




## Review

# Causal Impacts of Epidemics and Pandemics on Food Supply Chains: A Systematic Review

Brenda Cardoso <sup>1</sup>, Luiza Cunha <sup>1</sup>, Adriana Leiras <sup>1,\*</sup> , Paulo Gonçalves <sup>2</sup>, Hugo Yoshizaki <sup>3</sup> , Irineu de Brito Junior <sup>4</sup>  and Frederico Pedroso <sup>5</sup>

<sup>1</sup> Industrial Engineering Department, Pontifical Catholic University of Rio de Janeiro—PUC-Rio, Rio de Janeiro 22541-041, Brazil; brendafarias.eng@outlook.com (B.C.); luizarac@gmail.com (L.C.)

<sup>2</sup> Facoltà di Scienze Economiche, Università della Svizzera Italiana, 6900 Lugano, Switzerland; paulo.goncalves@usi.ch

<sup>3</sup> Production Engineering, Polytechnic School, Sao Paulo University, Sao Paulo 05508-220, Brazil; hugo@usp.br

<sup>4</sup> Environmental Engineering Department, Sao Paulo State University, Sao Jose dos Campos, São Paulo 12247-004, Brazil; irineu.brito@unesp.br

<sup>5</sup> Urban, Disaster Risk Management, Resilience & Land, World Bank, Washington, DC 20433, USA; fpedroso@worldbank.org

\* Correspondence: adrianaleiras@puc-rio.br; Tel.: +55-(21)-3527-1285/1286

**Abstract:** The epidemics and pandemics can severely affect food supply chains, including producers, retailers, wholesalers, and customers. To minimize their impacts, it is fundamental to implement effective policies that ensure continuity in the provision, affordability, and distribution of basic food items. This research identifies the main impacts of pandemics and epidemics on food supply chains and policies that can minimize these impacts. Based on a systematic literature review (SLR), 173 documents are analysed to propose a taxonomy of impacts on four supply chain links: demand-side, supply-side, logistics and infrastructure, and management and operation. The taxonomy presents the main impacts and respective mitigation policies. In addition, the literature review leads to the development of a comprehensive causal loop diagram (CLD) with the identification of main variables and their relationship with food supply chains. Finally, a specific research agenda is proposed by identifying the main research gaps. These findings provide a structured method for evaluating policies that ensure the functioning of food supply chains, particularly in disruptions such as epidemics and pandemics.

**Keywords:** COVID-19; food supply chain; epidemic; pandemic; disruptions



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## 1. Introduction

Disasters can trigger Supply Chain (SC) disruptions [1]. SCs operate at a level of high uncertainty during disaster response, which is very different from what most SC managers experience in regular operations [2]. During disasters, for example, companies face challenges such as time pressure, increased information uncertainty, and dynamic changes over time [3]. Besides, coordination among suppliers is difficult at best, which may disrupt SC flows.

Disasters demands efforts on food supply chains' (FSCs) resilience [4,5]. FSCs refer to all processes involved in food reaching the final consumer, including cultivation, processing, distribution, sales, and consumption [5]. FSCs need to operate in a relatively delicate balance between consumption, production, and inventory. Any disturbance in FSCs can cause instability due to delays between decisions and results, introducing oscillation and amplification [6,7]. Several factors can disrupt food supply chains, including political instability, droughts, floods, and infectious diseases [7,8]. FSCs are particularly susceptible to disruption because they are designed for efficiency and not for flexibility [9].

Most recently, the COVID-19 pandemic is significantly impacting FSCs [10–14], as breakdowns or bottlenecks in some elements have impacted other components up and

down their chains [11]. These increased impacts pose significant new challenges to organizations, requiring better designed and more effective inter-organizational collaboration at national and regional levels. A major challenge for companies during a pandemic is to implement systems (e.g., food production) resilient enough to continue functioning during a disaster [15]. To maintain the sustainability of their business, it is necessary to implement organizational practices [16].

Thus, this research aims to present the main impacts caused by pandemics and epidemics on FSCs and the related policies to mitigate their severity. Therefore, we seek to shed light on the following research questions:

- What are the main impacts of pandemics and epidemics on food supply chains?
- What are the main policies to mitigate the impacts of pandemics and epidemics on food supply chains?

This paper involves an exhaustive compilation of data and information through a Systematic Literature Review (SLR), collected from scientific documents and grey literature on pandemics and epidemics and the FSCs. We deliver three SLR possible outcomes proposed by [17]: a taxonomy, a framework, and a research agenda. The taxonomy, represented by tables evidencing impacts and policies, classifies the extant literature. The conceptual framework, illustrated through a causal loop diagram (CLD), synthesizes the literature based on our critical assessment. The research agenda poses propositions for new research [17].

Since the global food system is complex and the coupled relationships between different variables and effects are dynamic and nonlinear, it is critical to use suitable analytical modelling techniques, such as System Dynamics (SD). SD captures the dynamic complexity and the nonlinear behavior of complex systems over time and provides ways to understand the system behavior through feedback mechanisms [6]. Thus, SD enables a structured analysis of the food supply chain and policies to address the impact of the COVID-19 pandemic.

This study is relevant given the challenges faced by decision-makers in the context of pandemics and epidemics, in addition to the detrimental social impact that the subject involves. This paper builds upon a research gap on the impacts of pandemics and epidemics (e.g., COVID-19 pandemic) on supply chains that are not yet sufficiently discussed [1,12]. Previous research has discussed fragmented policies for the functioning of FSCs during crisis and emergency times; however, pandemics and epidemics need attention to the development of potential integrated policies to mitigate the risks of FSCs. Therefore, this paper brings a synthesis of academic literature related to the pandemics and epidemics' impacts and risk mitigation policies.

Following this introduction, Section 2 presents the research methodology. Section 3 reports the SLR and grey literature analysis, including a taxonomy and a framework (causal loop diagram). Section 4 presents a discussion, theoretical and practical implications, and a research agenda. Finally, Section 5 summarizes the concluding remarks, limitations, and future research avenues.

## 2. Materials and Methods

This research employs the method of Systematic Literature Review (SLR) through an eight-step process, as detailed in [18]: (i) planning and problem formulation, (ii) literature search, (iii) data gathering, (iv) quality evaluation, (v) data analysis and synthesis, (vi) interpretation, (vii) presenting the results, and (viii) review updating.

The research problem formulation has the two research questions presented in the Introduction. The second step encompasses a bibliographic search in both Scopus and Web of Science (WoS) databases, as they have a significant number of indexed journals [19]. The search considers three groups of keywords defined by a combination of keywords that covers the topic broadly enough to avoid any artificial limitation of the documents obtained while providing limits to exclude undesirable results [20]. The first group of keywords addressed the research SC focus. The second group includes impact terminologies. The

third group of keywords encompasses pandemic and epidemic terminologies. The set of keywords is as follows: (“suppl\* chain\*”) AND (food) AND (impact\* OR disruption\* OR security OR safety OR effect\* OR consequence\* OR break\* OR rupture\* OR influenc\*) AND (epidemic\* OR pandemic\* OR covid\* OR corona\* OR influenza OR sars OR mers OR ebola OR zika OR chikungunya)). The SLR, carried out on March 29, 2021, returned 534 documents without initial exclusions. The documents were analysed according to the following inclusion and exclusion criteria:

- Inclusion criteria: Research on the impact of pandemics and epidemics on FSCs, or research with proposed solutions for disruption in supply chains caused by pandemics or epidemics.
- Exclusion criteria: Research outside the context of pandemics and epidemics; research that does not address FSCs, or that addresses chain disruption for food poisoning.

Figure 1 summarizes the steps using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) diagram [21].

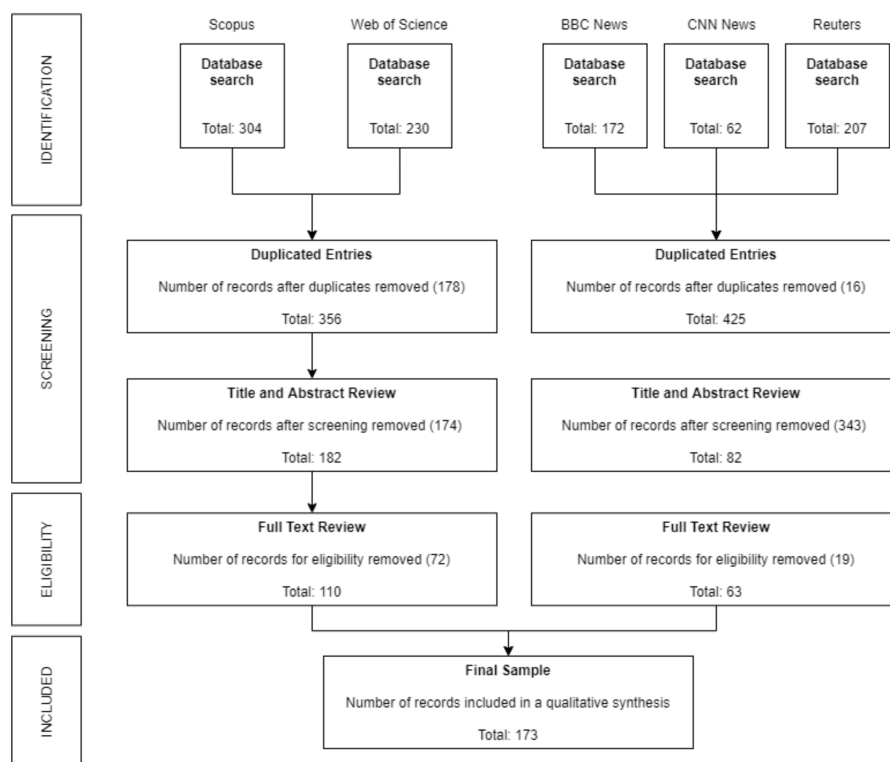


Figure 1. SLR search.

The stage of data collection is performed by employing auxiliary spreadsheets with the essential elements (impacts, policies, and strategies) and also categories of documents according to their research application [22,23].

The detailed description of the SLR ensured the quality evaluation stage. Each document has been reviewed independently by two reviewers. The agreement index between the reviewers was 94% when reading the abstracts, thus being considered acceptable [24]. The data analysis and synthesis are presented in the next section, describing the main results obtained from the documents' complete reading. Still, the paper synthesis is delivered through a taxonomy and a framework (causal loop diagram) with the leading SLR results. It is noteworthy that the impacts and mitigation policies are identified in this phase of the literature review through content analysis [25]. Mitigation policies are captured explicitly in the causal loop diagram reflecting the complexity and interconnectedness of the problem [6]. It is also worth emphasizing that there is no differentiation between

implemented and non-implemented policies, as this is not explicitly addressed in the analyzed documents. The discussion is based on how impact evaluation is addressed, considering a food supply chain perspective. The presentation of the results is described in the present paper. Updating of the SLR is proposed as future research.

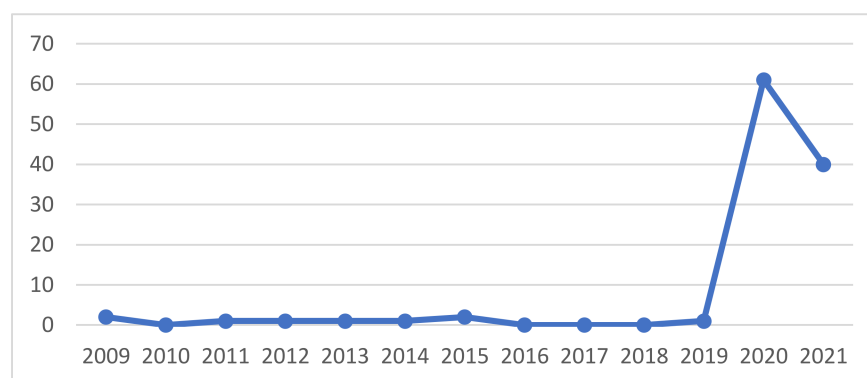
In addition to the peer-reviewed literature, this study also considers reports, news, and sites—what is called grey literature (441 documents). The search also considers the topic of pandemics and epidemics impact on food supply chains. It is worth mentioning that the grey literature review is carried out in the context of the COVID-19 pandemic since it is a current disaster at the time of this research. Therefore, to perform the search in grey literature, the Google platform was used in the advanced search option. In this way, the query used for the search regarding the FSCs is: ('covid-19 OR coronavirus' 'impact OR disruption' food "supply chain"). The search was carried in three major international sites (BBC News World, CNN News World, and Reuters) and considered documents from 11 March 2020 (the date on which WHO declared the COVID-19 pandemic) until 29 March 2021.

### 3. Literature Analysis

The following sections present descriptive and content analysis that lead to taxonomies for the main impacts of pandemics and epidemics in food supply chains, as well as respective mitigation policies. Additionally, this section also presents our proposed framework (causal loop diagram).

#### 3.1. Descriptive Analysis

Figure 2 shows the evolution of documents per year, the first one appearing in 2009. In the years 2009 and 2010, the world faced the H1N1 flu pandemic, leading to the appearance of publications in this field of study. The peak is reached in 2020 (61 documents) due to the recent coronavirus pandemic.



**Figure 2.** Evolution of publications per year until March 2021 (academic literature).

Regarding the type of publication of the SLR documents (academic literature), 80% are articles published in academic journals; of these, 11% are review papers, and the other documents are divided between papers published in conference proceedings, book chapters, and notes.

Concerning publication channels of the SLR documents (academic literature), Table 1 presents the SLR documents by periodic/journal. Sustainability stands out with nine publications, followed by the Canadian Journal of Agricultural Economics, which has seven works on the topic. Global Food Security, Agricultural Systems, and EuroChoices have five papers each. Those publications are inserted in journals related to sustainability, business, nutrition, development, and economics, which characterize the theme as multidisciplinary.

**Table 1.** Publication channels (academic literature)

Periodic/Journal	Quantity
Sustainability (Switzerland)	9
Canadian Journal of Agricultural Economics	7
Global Food Security	5
Agricultural Systems	5
EuroChoices	5
China Agricultural Economic Review	4
Food Control	3
World Development	3
Applied Economic Perspectives and Policy	3
International Journal of Environmental Research and Public Health	3
Food Security	3
Others	60

Regarding the characteristics of products/supply chains, various documents discuss product perishability, due to their high risk of waste during such disruptions. Most documents address impacts on the food supply chain as a whole; that is, they do not specify the type of food or supply chain (e.g., 1,3,12,13). Some documents focus on certain products or supply chains (e.g., agricultural products; such as grains [26,27], cereals [28], oilseeds [26], fruits [29], dairy [30,31], and fresh foods in general [7,8,11]. Other documents address the seafood SC [32,33], aquaculture sector [34,35], food and beverages [36], beef [37,38], pork meat [39,40], poultry industry [41], and eggs [39].

Most documents that specify the type of food or supply chain are related to agriculture and agri-foods. This result can be explained by the significant impact that pandemics and epidemics have on this sector. In the case of the COVID-19 pandemic, there were direct and indirect interruptions in the agricultural sector after the immediate onset of the pandemic [42,43]. For instance, agricultural supply chains struggled to keep up with impacts such as panic buying, changes in food consumption patterns, and loss of household income [43]. However, there will also be long-term implications for the sector after the pandemic ends [42,43], such as the need to redesign supply chains, increase flexibility, investment of capacity, and collaboration between stakeholders.

### 3.2. Content Analysis

Previous literature recognizes the importance of analyzing the impacts and vulnerabilities of FSCs to mitigate risks of interruption. Identifying the various ways food systems may fail is fundamental so that stakeholders, especially government officials, may prioritize actions and plans accordingly [44].

Content analysis is performed by fully reading each document and categorizing their data. Categorization, in turn, is an essential tool for systematic analysis of documents, based on an iterative process with a constant interplay of tests, reviews, and data comparison. Thus, this paper considers the impacts and policies from each document (Appendix A). The classification of these impacts and policies results in categories of FSCs in the context of pandemics and epidemics (Table 2).

Impacts are grouped into nine categories: human resources constraints; SC instability; financial and economic constraints; logistics disruption; infrastructure disruption; relationships between stakeholders; difficulty for accessing services and materials; consumer behavior; and unemployment and reduced income. Policies are grouped into categories according to their associated impact.

Table 2. Impacts and policies (summary).

Impact Category	SC Link				Policy Category
	Supply-Side	Demand-Side	Logistics and Infrastructure	Management and Operation	
Human resources constraints	X		X	X	Workforce assessment and monitoring Workforce adjustment Activities automation Health safety protocols
SC instability	X	X	X	X	Stability and business continuity plans Government financial assistance for companies Cooperation and collaboration Online infrastructures Decision and communication support tools
Financial and economic constraints	X		X	X	Economic and cost reduction plans Government awareness of economic impacts
Logistics disruption	X		X	X	Decision and communication support tools Government financial assistance for companies Online infrastructures Transportation and distribution plans
Infrastructure disruption	X		X	X	Restructuring plans Online infrastructures Workforce adjustment
Relationships between stakeholders	X		X	X	Communication technologies Cooperation and collaboration
Difficulty accessing services and materials	X		X	X	Government financial assistance for companies Contingency plans Cooperation and collaboration
Consumer behavior	X	X		X	Demand analysis plans Information-sharing tools
Unemployment and reduced income		X			Social support programs Food security plans Government financial assistance for population Workforce adjustment

Additionally, this study identifies the affected SC link: supply-side; demand-side; logistic and infrastructure; and management and operation. Food supply chains had to adjust rapidly to demand-side shocks and also plan for any supply-side disruptions [45]. Moreover, it is necessary to define strategies for impacts on logistics and infrastructure, and management and operation perspectives [46].

One of the significant impacts of pandemics and epidemics on the FSCs is on human resources constraints. In the COVID-19 pandemic, specifically, staffing shortages (not enough workers) have become a significant problem in several countries [38]. Restrictive movement measures (e.g., lockdown) caused labor shortages, which affect activities in



the food supply chain, harvesting, processing, and distribution [8]. Consequently, as the availability of human resources is lower, the disruption in the normal flow of activities in the food supply chain increases. Cargo transportation companies (e.g., airfreight) and the agriculture sector are links severely impacted by the lack of personnel [38,47,48].

SC instability is another impact highlighted by some authors. During the COVID-19 pandemic, oscillation of food prices can be observed [11–13,49]. Price increases might be partially due to supply-side disruptions [50,51]. Trade frictions could also affect global food prices [52]. Some authors still address the impact of instability in food supply and demand during pandemics and epidemics [5,53,54]. Supply and demand fluctuation, in general, can trigger instability of inventory levels [55] since most organizations are not prepared to operate in crisis and emergency scenarios. Consequently, companies in all sectors are targets of financial losses and increases in operating costs [29,53,54,56–58], adverse effects for business growth and productivity [57,59,60], delays and interruptions for the delivery of products, and problems in packaging materials [38].

Financial and economic constraints also have significant impacts on FSCs. During pandemics and epidemics such as the COVID-19, companies may suffer from a lack of working capital, given that operational costs have increased [61,62].

Logistics and infrastructure impacts are also highly cited (e.g., [58,63–67]). Disruption in transportation, for example, can be traced back to the unavailability of labor, since laborers often need to stay at home and are unavailable to carry out their activities due to social distancing policies or infected workers [45,68,69]. Movement restrictions are also considered an impact since some countries block or restrict the export of basic products to guarantee national food security [70]. From this perspective, it is also possible to identify that the occurrence of pandemics and epidemics affects food distribution [71–73]. Once a pandemic or epidemic affects the trade of goods (e.g., additional border controls; export restrictions; import restrictions), product movement is also a highly mentioned supply-side impact [52,74–76]. The interruption in supply chain movements results in a cascading effect on producers and traders [77]. Furthermore, during COVID-19, partial or total blocking measures resulted in the closure of schools, universities, workplaces, shops, and non-essential restaurants. Those restrictions changed the means to food access and served as another obstacle to distributing food to populations [73]. Some companies had to close for cleaning purposes [36], while others (e.g., slaughterhouses) had to close due to the high number of infected people.

Some authors mention the relationship between stakeholders as an impact during pandemics and epidemics. During a disaster, organizations face challenges, for example, related to great information uncertainty [3], which hamper communications between links in the supply chain. In addition, as pandemics hit supply chain infrastructure, business relationships can be undermined [61]. The difficulty in accessing equipment, services, and materials also impacts FSCs, especially for producers. The COVID-19 pandemic, for example, affected the agricultural sector, disrupting the supply of inputs (e.g., fertilizers, seeds, machinery, workers, and extension services) thus affecting production systems and supply chains [78,79].

The change in consumer behavior during pandemics and epidemics also interferes negatively with FSCs, especially on the types of products purchased. During a disaster such as the COVID-19 pandemic, people become cautious about their spending, buying less often but in larger volumes, preferring small grocery stores, and purchasing food online to avoid agglomerations [13,80,81]. The initial peak in demand due to panic buying behaviors was also a problem [82,83]. Panic buying of household items and store cupboard staples such as rice and flour has occurred in nearly every country hit by the virus [38]. Panic buying behavior typically originates from customers who buy more than usual and not restricted food availability. This trend was partially driven by the media, which often showed pictures of empty shelves and warned of food shortages [84]. It also affected people from all income classes, including lower-income populations [85].

All those impacts, as mentioned earlier, contribute to food insecurity of the vulnerable population. Food security is a global concern and is a challenge for many middle- and lower-income countries [87]. The economic slowdown caused by COVID-19, with consequent job losses, decreased income, and disruption in SC, seriously threatens food security [28]. Therefore, food systems need to adopt robust strategies and policies to correlate the needs of producers, farmers, workers, low-income consumers, distribution, and the food chain as a whole [58,74]. Strategies and policies are essential to social measures, once they must guarantee income access for all families and actions designed to protect vulnerable populations. Among the proposed policies, the following stand out: social protection and food programs [5,82]; measures as social assistance and incentive [28,82]; and, aid and food donations [28,74].

### 3.3. Framework (Causal Loop Diagram)

[illegible]

**Figure 3.** CLD with variable relationships.



Given the context of the COVID-19 pandemic, the CLD captures in the top right of Figure 3 a simple SIR (Susceptible, Infected, Recovered) model. The SIR is widely employed to model epidemics, such as Ebola, MERS, SARS, and Malaria [88]. The reinforcing loop R1 captures the contagion process that diffuses the epidemic. As the disease progresses, it infects healthy individuals closing the balancing loop B1 (depletion).

Among the infected individuals, some recover (e.g., balancing loop B2—recovery) and some people die (e.g., balancing loop B3—death). The larger the infected and dead populations, the larger the impact on economically active individuals, and the smaller the number of active workers. As the number of infected, deceased, and hospitalized increase, heightened awareness and critical public opinion pressure policymakers to implement public health policies that can curb the diffusion of the epidemic (closing a balancing loop that implements social distancing measures).

Social distancing measures, quarantines, and mobility restrictions to avoid contact and reduce the infection rate prevent workers (e.g., susceptible and at-risk populations) from going to work, reducing the number of available workers and increasing the number of employees receive salaries. An additional impact to the number of active workers includes the infected, hospitalized, and dead. As the number of people out of work increases more households face income loss, and more families are exposed to food insecurity. Furthermore, food price rises and food shortages [89], increase food insecurity in vulnerable families. Balancing loop B7 (food security impact on restrictions) captures this effect (center, Figure 3). Families that cannot afford to buy food without a steady stream of wages must return to work even if social distancing measures may still be in effect. Balancing loop B6 (food security due to financial assistance) captures the need for government to implement public policies to assist the vulnerable population and prevent them from facing unprecedented problems (bottom center, Figure 3).

As quarantines and social distancing measures reduce overall consumption and economic activity, firms face increased financial stress. Firms that have no means to retain employees must lay them off (reinforcing loop R3—layoffs due to financial stress). As more firms struggle and layoffs increase, government awareness of these economic impacts also increases, leading policy-makers to provide financial assistance to enterprises (loop B5—pressure for financial assistance; at bottom center, Figure 3).

Finally, unavailable workers and firms' stress also affects the food supply chain (FSC) productivity, captured by reinforcing loop R4 (HR & Financial Constraints; center left, Figure 3). Thus, producer inventories will likely face a series of disruptions mentioned in the literature, encompassing disruptions in production, transportation, distribution, storage, among others (captured by loops B8 and B9; left, Figure 3).

All variables presented in the CLD come directly from the SLR. In addition to the variables directly related to the SLR findings (e.g., HR & Financial Constraints), the CLD also captures variables (e.g., social distancing measures included in the health and safety protocols category) identified in the broader epidemiological and public policy literature in a systemic and consistent way.

#### 4. Discussions, Implications and Research Agenda

This section presents the research discussions and implications (Section 4.1) and the research agenda (Section 4.2).

##### 4.1. Discussions and Implications

The study highlights the impacts of pandemics and epidemics (e.g., COVID-19 pandemic) on FSCs and the policies needed to mitigate their consequences. The results reinforce the importance of identifying the different sources of impacts and implementing effective policies to ensure business continuity. The implementation of mitigation policies must be broad enough to guarantee the continuity of supply, accessibility, and distribution of essential foods. In addition, the food system (e.g., procurement, production, distribution, marketing) must be flexible enough to meet the shifting population demand, as well as

stable and continuous enough to guarantee continuous supply, while minimizing the impact of possible disruptions. Considering that an SC is a complex system involving different stakeholders, interruptions in any SC link may affect all links in the chain. These impacts can be classified into supply-side, demand-side, logistics and infrastructure, and management and operation.

From a supply-side perspective, human resources constraints, characterized by loss of life, and poor physical health requiring hospitalizations, sick leaves, and increased absenteeism, stand out as the main impact caused by epidemics and pandemics. In addition to poor physical health, human resource constraints can also be caused by psychological and social factors such as feelings of sadness, apathy, fear, uncertainty, frustration, anxiety, insomnia, and others [90]. Activities automation is frequently mentioned (e.g., [8,56,91]) as a policy to mitigate this impact. Food production activities must be mechanized and automated using intelligent technologies so that human interference is minimal [8].

Concerning the demand side, the most significant impacts include changes in consumer behavior, unemployment, and reduced income. Uncertainty during disasters causes consumers to restrict spending, buying only necessary items. Therefore, measures and indicators to monitor the demand need to be analyzed to allow a holistic view of the disaster effects [64] and to understand customer needs that can be identified through digital and analytical techniques [36].

Regarding logistics and infrastructure, a critical impact deals with the closures of units in the supply chain. To meet specific security measures and movement restrictions, warehouses, manufacturing units, wholesale markets, and other units have been forced to close for different durations. The pandemic has also created additional demand for internet-based activities, such as online shopping, distance education, online doctors, services, and home office. Therefore, measures that facilitate the work adaptation to those job opportunities are necessary for the new reality [92].

From management and operations perspectives, SC instability is highlighted as the top impact (e.g., fluctuations in demand and supply). In the COVID-19 pandemic, specifically, as governments intensified social distancing policies, many consumers resorted to panic buying due to restrictions on movement and fear of shortages [45]. This also resulted in instability in the food supply. Implementing techniques and technologies to analyze supply and demand behavior is necessary to assist SC activities [36]. SC instability also involves food waste. During the first months of the COVID-19 pandemic, for example, perishable FSCs posed higher risks of waste, along with logistical, operational, financial, and health risks [14]. Short-term food waste is caused by changing patterns of consumption, including, excessive purchase and improper storage of large amounts of food [84]. Long-term food waste is caused by FSCs interruptions due to restrictions on the movement of goods, causing product accumulations and high levels of food loss. Conventional or Innovative techniques must be implemented to minimize the negative effects of this impact [77], such as wet peatland innovation, known as “paludiculture” [93].

The literature review’s findings also provide insights into the differences between short-supply chains (SSCs) and long-supply chains (LSCs). Comparability between SSCs and LSCs is an emerging topic that can assist in strategies during and after pandemics and epidemics. With the occurrence of the COVID-19 pandemic, for example, LSCs were affected by special disaster response measures (e.g., restriction on the movement of goods between countries) [93,94]. To a large extent, SSCs did not face similar sanctions. Therefore, there is a need to adjust operations considering the strength of SSCs. SSCs perform a fundamental role in reinforcing the resilience of food networks, contributing to the stability of access to food in periods of crisis such as pandemics and epidemics [95,96]. Our review suggests that the development of local suppliers and investment in local production are examples of policies to mitigate epidemics and pandemics in SSCs.

Besides, during pandemics and epidemics, FSCs receive greater attention from researchers, specialists, and professionals as they pose high logistical, operational, and financial risks [14], aggravated by product perishability. As a result, there is an increased

interest in applying policies, strategies, tools, and techniques to improve the FSCs management. While the policies listed in this article are specific to FSCs (e.g., crop insurance subsidy and food banks), some of them can also be adapted to non-food supply chains such as the automobile SC. Non-food SCs also need policies for business continuity during crises. Some policies identified in this paper (see Appendix A) can be easily adapted to the context of other supply chains, for example, identification and strengthening of local suppliers, investment in local production, government assistance, identification of alternative suppliers and distributors, demand analysis through analytic and digital techniques and collaboration between the SC links.

Regarding the CLD, the framework summarizes the impacts and policies of pandemics and epidemics on the FSCs identified in the literature. It highlights the impacts on active workforce [1], which generate effects on operations (e.g., production, distribution, storage) and the supply chain's productivity. Reduced availability of the workforce also reduces populations' income which increases the population's risk of food insecurity [28]. The CLD also presents the financial stress of companies. Financial stress involves reduced working capital, increased costs [61,62], and effects on SC stocks. As the adverse effects caused by epidemics and pandemics increase, the population pressures policymakers to implement health policies, social policies, and financial policies to minimize them.

These findings contribute to the discussion of food security and improvement in the management of organizations during pandemics and epidemics. Regarding theoretical implications, this study advances the discussion of impact management through a broader approach, involving SC links, impact categories, and policy categories related to FSCs. It lists pandemic impacts in detail and simultaneously shows respective mitigation policies. Complementing the results, we developed a causal loop diagram to identify cause and effect relationships between main system variables during pandemics, such as the COVID-19 pandemic. In terms of practical implications, identifying the potential impacts of supply chain disruptions is a challenge for organizations. This paper presents both a taxonomy and a framework together with a detailed list of categories that should be considered when mapping impacts and implementing policies. Consequently, this study helps create supply chains that are more resilient and prepared for possible future disruptions.

#### 4.2. Research Agenda

Informed by the main insights available in the SLR and grey literature, our analysis identified potential gaps and highlighted several opportunities for future research in the context of disaster impact assessment in FSCs:

- Analysis of other types of disasters;
- Analysis of vulnerable groups;
- Analysis of disaster risk management in companies;
- Analysis of cascading effects;
- Analysis of risk sources;
- Analysis of sustainability dimensions;
- Comparative analysis between short-SCs (SSCs) and long-SCs (LSCs)
- Analysis of prevention and mitigation strategies.

Our study focuses on mapping and understanding impacts caused by pandemics and epidemics on the FSCs. However, the analysis of effects of other disasters (e.g., floods, earthquakes, refugee crises, fires) allows identifying strategies to guarantee food supply and minimize adverse interruption effects. In cases of earthquakes and floods, roads are obstructed and transportation is significantly affected. In cases of refugee crises, there is a need to purchase and distribute food in a way that meets everyone's needs. This research can be adapted to other types of crises affecting the food SC such as foot and mouth disease or political crises such as Brexit, considering the particularities of each case.

Besides, some social groups are more affected during disasters than others due to their high degree of vulnerability (e.g., food-insecure populations). Identifying and analyzing vulnerability groups to disasters is an essential mechanism for the assessment and

implementation of vulnerability mitigation policies. Regarding the FSC, plans and policies must be related to ensuring food security to maintain availability, accessibility, and quality of food.

Also, studies that address supply chain risk management (SCRM) practices in companies are crucial sources of data and information. SCRM tools and practices in FSC can help business continuity and ensure food quality. SCRM is also important to ensure population food safety. Other than that, it is essential to highlight that the entire supply chain is affected due to cascading effects that occur between different echelons of the food system. Problems arising from disruptions spread among suppliers, producers, retailers, wholesalers, and all links in the supply chain. Thus, studies that indicate strategies and policies for flexibility and collaboration among stakeholders are essential for organizations to improve information sharing and communication to improve decision making. Collaboratively, FSC links can obtain better results than can be achieved independently and can have benefits such as reduced costs.

There are significant effects on supply chains that are due to sudden-onset natural disasters (e.g., earthquakes, floods, hurricanes). However, other sources of risk can cause disruptions to the flow of materials. Identifying and analyzing different sources of risk, such as man-made disasters, can shed more light on mitigation measures to FSC.

It is also essential to consider the sustainability dimensions of food supply chain operations during pandemics and epidemics. As the COVID-19 pandemic highlights, the three sustainability dimensions—social, environmental, and economic—are inextricably linked [93,97], suggesting opportunities for future research, including natural experiments, empirical investigation, and field and case studies [97].

Furthermore, research related to the degree of vulnerability in short- and long-chains is needed. In general, the authors state that short chains play an essential role in reinforcing the resilience of food networks, contributing to the stability of access to food in periods of crisis [95]. In this way, short chains can strengthen the resilience of the food supply [80,93,96]. Still, it is essential to analyze the particularities of each type of supply chain to understand the advantages and disadvantages of different policies as well as intrinsic issues associated with implementation and adaptation.

Finally, organizations must be adequately prepared to meet changes in markets, consumer behavior, and supply chain flow caused by a disaster. For this reason, studies that assess how organizations are prepared or are preparing to respond to an emergency are necessary and provide feedback for other organizations. The mitigation plans will help them prepare for the next disruptions (e.g., pandemics and epidemics).

## 5. Conclusions

The research presents findings that can collectively be considered a reference for stakeholders involved in planning pandemic and epidemic response scenarios.

The results concern identifying the most academically cited impacts and the proposed policies and strategies to mitigate FSCs disruptions. Also, the SLR allows the development of a CLD with the identification of the main variables and their relationship, as well as a research agenda with main future opportunities.

For the systematic literature review, the study considered 975 abstracts. Based on the exclusion criteria 173 documents remained for the content analysis of pandemic and epidemic impacts on FSCs. These 173 documents provide the sources used to gain knowledge and synthesize our understanding of the impacts of pandemics and epidemics on FSCs, leading to our contributions, including (a) the theoretical foundation for the main concepts of impacts of epidemics and pandemics on food supply chains and (b) the definition and development of the proposed taxonomy, framework, and research agenda.

The identification of SC links through a taxonomy (supply-side, demand-side, logistic and infrastructure, and management and operation) facilitates understanding of the impact associated with the implementation of policies. The development of the CLD presents a cause-and-effect relationship associated with the implementation of health, social and financial assistance policies. Finally, the research agenda presents opportunities for future research considering research gaps and emerging topics.

In analyzing this research area, our study contributes insights for academics and professionals on the impacts of disasters on food chains and appropriate policies to mitigate them. Given the increased likelihood of future disasters, the development of more resilient supply chains represents a future necessity. Still, our study has limitations, such as the focus on specific policies for the food supply chain. Pandemics and epidemics, and more broadly disasters, can affect different SCs. Therefore, there is a need to evaluate the implementation of these policies in other chains or even identify and propose new policies considering different SCs (e.g., automobile, vaccine, health supplies).

In addition to the research agenda's main topics, updating the literature review and using simulation tools, such as the SD model, is also suggested. The ability to simulate the dynamic behavior and to test the consequence of different policy options allows policymakers to evaluate their decisions' short- and long-term results [98]. In this way, it will be possible to simulate different scenarios, identified through the policies and strategies, and propose appropriate and concise guidelines to help decision-makers. Although there is no differentiation between implemented and non-implemented policies, our paper presents a detailed list of mitigation policies associated with each impact identified in our systematic literature review. Further research identifying and assessing the effectiveness of mitigation policies in pandemics and epidemics, can further validate the results obtained by other theoretical studies.

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## Appendix A

Table A1. Impacts of pandemics and epidemics and respective mitigation policies on FSCs.

SC Link	Impact Category	Impacts [References]	Policy Category	Policies [References]
Supply-side; logistics and infrastructure; management and operation	Human Resources constraints	Absenteeism, unavailability or quarantine, or refusal to work in unsafe conditions [1,8,27,29,31,36–38,40,41,45,47,48,50,57,58,60,63–65,68,69,72,73,78,80,82,84,87,91–93,99–130]	Workforce assessment and monitoring	Absenteeism monitoring [69] Risk monitoring [103] Multiple sourcing [131] Information management and policy coordination with governments [12]
			Workforce adjustment	Guidelines on seasonal workers and migrant workers [10,111] Temporary workers [80,114] Remote workforce training [93] Optimizing the familial or community workforce [87]
			Activities automation	Mechanization and automation of activities with technology [8,56,79,101,132] Digital agronomic trainings and information through programs facilitated collaboratively with government [79] Computer-based statistical models [101] Greater reliance on automation [113]
			Health and Safety Protocols	New health and Safety Protocols [29,36,78,80,84,101,103,114,131–133] Use to personal protective equipment and sanitary measures [14,72,104,116,119,121]
Supply-side; logistics and infrastructure; management and operation	SC instability	Price instability [4,7,10–14,25,28,29,38–41,47–52,57,58,60,63,66,70,72,75,78–82,84,87,89,92,96,101,102,105,107–109,111–113,115,125,132–160]	Stability and business continuity plans	New practices for food safety and social responsibility [16] Guidelines against price gouging [109] Guarantee the supplementation of food in distribution centers [136] Strong, focused country leadership [89] Food price monitoring schemes [75,78,84,109] Multiple sourcing [131]
			Government financial assistance for companies	Government food prices surveillance; price monitor [10,89] Direct assistance to farmers [102] Crop insurance subsidies [133] Farm support payments [133] Food price subsidies [79]
			Cooperation and collaboration	Information management and policy coordination with governments [12] Public-private cooperation [60]



Table A1. Cont.

SC Link	Impact Category	Impacts [References]	Policy Category	Policies [References]
Supply-side; demand-side; logistics and infrastructure; management and operation	SC instability	Sales fluctuation [11,29,31,36,56,60,72,79,80,100,102,108,111,121,154,161]	Stability and business continuity plans	Adjusting marketing strategies [36] Strengthening their positions in retail and online markets [29,114] Diversification of product lines to fill alternative markets [56]
			Government financial assistance for companies	Reduction of fees and taxes [66]
			Online infrastructures	Food delivery app and logistics company [92] Online platforms [29,114,161]
			Cooperation and collaboration	Link farmers and restaurants directly to food banks [58,114]
Supply-side; logistics and infrastructure; management and operation	SC instability	Inventory instability; restocking become harder; storage difficulties [31,41,50,62,79,110,115,135,152,155,162]	Decision and communication support tools	Information and communication availability [54] Direct payments for inventory were made to cattle producers [102]
			Stability and business continuity plans	Operational and contingency plans [41,68] Manage both operation and inventory [41] Synchronize strategic processes [46] Policy support for infrastructure development such as storage, cold chains and pack houses [105]
			Cooperation and collaboration	Private or government institutions need to invest in storage centres [132]
Supply-side; demand-side; logistics and infrastructure; management and operation	SC instability	Order's cancelations and rescheduling [10,13,36,39,72,79,101,102,105,113,115,126,154,163–168]	Stability and business continuity plans	Limit exposure to the international market and meeting local demand [34] Additional safety stock [166]
			Cooperation and collaboration	Collaboration with suppliers and deadline agreement [167]
Supply-side; logistics and infrastructure; management and operation	SC instability	Production volume changes (production rate) or stopping production (stoppage of production) [7,10,12,38,48,56,63,66,70,72,74,75,79,80,87,100,106,108,110,113,114,129,131,134,137,142,152,162,169–174]	Stability and business continuity plans	Local produce/ slow food [134,170] Strengthening consumer demand [171] Alternative materials and to source local substitutes [101] Compensation measures [161] Regular training for their employees [80] Innovative systems (e.g., aquaponics and aeroponics) [70,74]
			Cooperation and collaboration	Policy coordination with governments and development of new manufacturing strategies [12] Supply chain partnership [101]
			Decision and communication support tools	Integrated governance of food systems at regional Level [134]

Table A1. Cont.

SC Link	Impact Category	Impacts [References]	Policy Category	Policies [References]
Supply-side; demand-side; management and operation	SC instability	Fluctuation in supply and demand [5,7,8,14,25,28,29,36–39,41,46– 48,50,54,57,60,63,64,74,76,78–81,84,92,93,100–102,105– 108,111,114,118,123,125,131,132,137,139,142,144,146,149, 155,159,164,169,170,175,176]	Government financial assistance for companies	Simplifying the use of financing instruments in rural development programs [111] Support farmers with output-based and credit-based (interest subsidy) subsidy [78,152,162] Flexibility for companies [172]
			Online infrastructures	Accelerating the development of e-commerce [80]
			Stability and business continuity plans	Synchronize strategic processes [46] Strengthening their positions in retail and online markets [29] Operational and contingency plans [41,68] Mitigation and prevention measures [45,68,164] Declaring minimum support price or fair price [34] Promotion of short food chains and local products [80,107,111,131,144] More diversified production and supply networks [74] Alternative suppliers and distributors [36] Inventory policies [101] Strategic autonomy [123]
				Information and communication availability [54] Ensure the smooth connection of supply-and-demand information [161] Demand analysis thought analytic and digital techniques [36,132]
				Visibility and coordination among FSCs [131] Cooperative organizations with local producers [93]
				Online ordering and home delivery [131]
			Online infrastructures	Online ordering and home delivery [131]
Supply-side; management and operation	SC instability	Business growth and productivity [57,60]	Stability and business continuity plans	Operational and contingency plans [41,68] Business continuity plan [103] Mitigation and prevention measures [45,68,164]

Table A1. Cont.

SC Link	Impact Category	Impacts [References]	Policy Category	Policies [References]
Supply-side; management and operation	SC instability	Food Waste [11–13,15,29,31,37,46,58,67,71,72,77,83,84,87,93,96,110,115,116,132,136,154,169,171,177,178]	Decision and communication support tools	Conventional or innovative techniques [77,93,132] Informations management [12,169]
			Cooperation and collaboration	Collaboration between the SC Links [12,171] Food trade transparency [171]
			Stability and business continuity plans	Promote sustainable development [11] Bioactive components [132] Additional collection and processing centres [132] Food loss and waste prevention actions [84] Management of food waste [67] Redistributing surplus food [67,110] Processing of alternative products with an enhanced shelf life to reduce waste [46,72] Raising food-waste awareness [87]
Supply-side; management and operation	Financial and economic constraints	Reduction of return on investment and reduction of the industry's contributions to GDP [61]	Economic and reduce costs plans	First Expired, First Out method [61] Partial sacrifice of remuneration agreed to by employees and employers [61] Extended office time after the crisis period [61] Minimize trade promotion costs [61] Utilize weekends and holidays as working days [61] Product rotation in trade [61] Focus on building online infrastructures [61]
Supply-side; management and operation	Financial and economic constraints	Shortage of working capital and delay in opening letter of credit [61]	Economic and reduce costs plans	Minimize trade promotion costs [61] Focus on building online infrastructures [61]
Supply-side; logistics and infrastructure; management and operation	Financial and economic constraints	Economic losses and costs of operations (increased costs of production) [14,29,41,54,56–58,62,72,100,102,105,108,121,149,159]	Economic and reduce costs plans	Focus on building online infrastructures [61] Change of production focus (e.g., toward production of hand sanitizer or similar) [72] Reshape strategy for business continuity through stress-testing to evaluate short-term liquidity and risks [93] Downsizing their workforce in order to reduce operational costs [72] Cost reduction and elimination of non-essential assets [149] Remote support centers [62] Crisis committee creation [62]

Table A1. Cont.

SC Link	Impact Category	Impacts [References]	Policy Category	Policies [References]
Supply-side; logistics and infrastructure; management and operation	Logistics disruptions	Transport disruptions; transport restrictions; delays in transportation [1,8,10,13,15,29,36,38,45,47,48,51,56–58,63–66,69,72,75,79,82–84,89,99,100,108–115,123,126,127,131,135,137,157,162,163,178,179]	Government awareness of economic impacts	Economic aid in the form of so-called “relief packages” [93,108] Reduction of the turnover tax rate for all small and medium enterprises (SMEs) [66] Effective financing for companies [89,164]
			Decision and communication support tools	Decision Support System (DSS) [Erro! Fonte de referência não encontrada.] Smart packing technology [8]
			Government financial assistance for companies	Government’s assistance [10,33,78,79,108]
			Online infrastructures	E-commerce between farmers with consumers [84,114,132] Delivery through communication applications [114,135]
Supply-side; logistics and infrastructure; management and operation	Logistics disruptions	Restrictions of movement of goods (e.g., border restrictions; export restrictions; import restrictions) [7,10,14,27–29,33,36–38,48,52,58,70,73–76,78–84,89,99,107,111,113,115–118,123,127,131,137,139–142,146–149,152,157,158,163,165,174,180–182]	Transportation and distribution plans	Policy actions that ensure minimum transportation bottlenecks [109] Opening ‘green lane’ border crossings to all freight vehicles [111] Alternative transportation modes [131] Ships and trains can also be used for fresh foods [131] Local suppliers [101,109]
			Transportation and distribution plans	Local suppliers and local production [101,180] Keep trade open [48,114] Selling the products in the domestic market [113] Keep major exporters from enacting trade restrictions [27] More diversified production and supply networks [74,114]
			Decision support tools	Increasing trade transparency and traceability [34] Digital technologies to monitor harvest [182]
			Government financial assistance for companies	Relaxation of laws and impositions [33,114,159] “Green lanes” [127] Improve community groups to distribute food [182]
Supply-side; logistics and infrastructure; management and operation	Logistics disruptions	Food distribution disruption [1,13,29,36,37,50,57,58,60,66,67,71–73,75,79,80,84,92,100,106,108,118,136,140,142,171,183]	Decision support tools	Decision Support System (DSS) [3]
			Online infrastructures	E-delivery services; online platforms [8,135]
			Transportation and distribution plans	Short-term incentives for distributors [61] Distribution planning and resource allocation [14] Strengthening food storage and inter- and intra-island transport [171] Distribution strategy [67]

Table A1. Cont.

SC Link	Impact Category	Impacts [References]	Policy Category	Policies [References]
Supply-side; logistics and infrastructure; management and operation	Infrastructure disruptions	Shutdown of processing plants; closure of businesses (momentarily or not) [10,13,14,29,31,37–41,47,48,51,58,64,78,83,84,93,102,103,106,107,110,111,113–116,121,123,126,128,132,134,140,142,149,156,157,169,171,173,178,184–186]	Government financial assistance for companies	Government humanitarian assistance [29,140] Reduction of fees and taxes [66,84,113] Government purchasing agricultural products from small farmers and shorter supply chains [84]
			Restructuring plans	Emergency cashflow and liquidity measures [93] Significant funds [29] Activate the agricultural crisis reserve [111] Divert products to other units [173] Market information [105]
			Online infrastructures	E-delivery services; online platforms [8,72,80,92,95,110,114,135]
Logistics and infrastructure; management and operation	Infrastructure disruptions	Constraints on storage space capacity [14,29,36,63,108,109,170]	Workforce adjustment	Relocating healthy staff from closed plants [170]
			Restructuring plans	Better warehousing infrastructure [109] Policy support for infrastructure development [105] Market support measures [111] Increasing hours of operation [170] Upskilling staff [36] Strong focused country leadership [89] New operating procedures [67]
			Online infrastructures	Focus on building online infrastructures [61]
			Government financial assistance for companies	Short-term incentives for distributors [61]
Supply-side; logistics and infrastructure; management and operation	Relationships between stakeholders	Information sharing between stakeholders [3]	Communication technologies	Information and communication availability [54] Improve communication skills [56]
			Cooperation and collaboration	Sharing of data and information [110,132] Collaboration between stakeholders [132] Coordination, cooperation, and support among stakeholders [78] Government supported scaling up digital information sharing models [135]
Supply-side; logistics and infrastructure; management and operation	Relationships between stakeholders	Trade relationships [48,61,82,154]	Cooperation and collaboration	Effective partnerships and integration [46,89] Product rotation in trade [61]

Table A1. Cont.

SC Link	Impact Category	Impacts [References]	Policy Category	Policies [References]
Supply-side; logistics and infrastructure; management and operation	Difficulty accessing services and materials	Difficulty accessing equipment and services [72,79,118,125,162]	Government financial assistance for companies	Government subsidies [110]
			Contingency plans	Assistance manuals and guidelines [79]
Supply-side; logistics and infrastructure; management and operation	Difficulty accessing services and materials	Input's supply (ex: seeds, fertilizer, and agrochemicals) [8,10,29,37,38,41,51,56–58,60,65,66,72,78–80,84,89,92,99,101,104,105,108,110,112,132,136,140,161]	Contingency plans	Diversify the supply chain [57,72] Local inputs [110] Establish and operationalize the food bank, community seed bank, and buffer stock of fertilizers [78] Increase inventory levels [131] Diversify the supply chain [161] Sustaining the critical agricultural inputs [131] Anticipated reducing product lines and/or ingredients used [72] Establish an efficient procurement and distribution system [78]
			Cooperation and collaboration	Public-private cooperation [60] Strength public-private-community partnership mechanisms [78]
			Government financial assistance for companies	Seed and other input supplies should be ensured (government) [10,65,110,140] Provide seeds and fertilizer to farmers in several countries [79] Contractual grain production agreements with farmer groups (advanced seed credit to farmers) [79] Subsidy programs and relief packages [38,79] Government supported programs [79]
Supply-side; demand-side; management and operation	Consumer behavior	Change in consumer behavior (food consumption patterns) [7,8,11,13,29,36,39,41,50,52,58,60,64,70–73,80,81,83,84,89,93,95,96,101–103,105,106,111,114,115,131,132,134,138,142,160,174,187]	Demand analysis plans	Operational and contingency plans [41,68] Synchronize strategic processes [46] Food surveillance measures should include consumer-eating habits [64] Innovative marketing and planning of the distribution [93] Relaxation of competition laws [187] Adjust payment methods to consumers' demands [93]
			Information sharing tools	Provide detailed information (e.g., webinars and podcasts) [114]
Demand-side; management and operation	Consumer behavior	Panic buying; panic of food shortages [7,8,14,25,27,29,41,47,48,50,57,58,64,70,73,75,81,83,84,87,92,95,96,105,106,109,111,113,114,129–131,133–135,139,152,155,161,165,169,170,177,188]	Information sharing tools	Efficient information sharing mechanisms [134] Publicly available food supply information [107,110,131] Transparent dissemination of information [10,95]



Table A1. Cont.

SC Link	Impact Category	Impacts [References]	Policy Category	Policies [References]
Demand-side	Unemployment and reduce income	Reduced income (consumer purchasing power; income changes) [7,13,28,29,37,43,57,58,72–75,78–80,83,84,87,89,92,103–105,108,109,111,112,125,131,134,135,137,138,140,143,147,164]	Social support programs	Measures as social assistance and incentive [82,112] Social measures (e.g., donations, increase income) [28,48,74,99,108]
			Food security plans	Use of food banks (food at a nominal price) [73,133] Maximize food consumption with minimum wastage [138] A subsidy for selected food products to restrict pricing [131] Governmental and non-government agencies partnership [131]
			Government financial assistance for population	Government supported programs [79,92,105,125] Tax relief according with the gross monthly income [66] Facilitate access to food and assist the population [138]
Demand-side	Unemployment and reduce income	Job losses; employee layoffs; unemployment [13,28,29,50,56,58,64,66,72,74,75,79,80,84,87,89,92,106–108,110,128,142,147,155,163,164,169,171]	Government financial assistance for population	Social insurance (e.g., unemployment benefits) [29]
			Social support programs	Food banks and other sources of food assistance [111] Social support programs [74,92,135]
			Workforce adjustment	Enabling remote working and learning [64,93]

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